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THE EFFECTS OF THE USE OF A VISUAL SIMULATOR IN TRAINING T-2C STUDENT NAVAL AVIATORS FOR CARRIER QUALIFICATION

by

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Two training squadrons of student naval aviators flying the T-2C Buckeye aircraft during their Intermediate Stage of Strike (Jet) Training were compared to identify any effects attributed to exposure to the T-45 Operational Flight Trainer, a state-of-the-art, visual, dome simulator. Students in VT-23 at Naval Air Station (NAS) Kingsville, Texas were exposed to demonstrations of carrier landings in the T-45 simulator prior to their carrier qualifications. A sister squadron at NAS Meridian, Mississippi (VT-19) did not receive exposure to the simulator. Both squadrons conducted carrier qualifications on the same dates and same aircraft carrier. A comparison of the squadrons considered the four measures of effectiveness (MOE): 1) squadron disqualification rates, 2) LSO trend analysis scores, 3) Aviation Training Form (ATF) CQ-11x performance evaluations, and 4) average grades for individual performance areas listed on ATF CQ-11x. Students in VT-23 had higher CQ-11x performance evaluations. When the performance evaluations are broken down to individual performance areas, VT-23 also has substantially higher grades in Pattern. Allowing for the importance that a proper flight pattern has on the approach and landing on the aircraft carrier, it is argued that exposure to the T-45 visual simulator had a positive effect on the students in VT-23.

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ABSTRACT

Two training squadrons of student naval aviators flying the T-2C Buckeye aircraft during their Intermediate Stage of Strike (Jet) Training were compared to identify any effects attributed to exposure to the T-45 Operational Flight Trainer, a state-of-the-art, visual, dome simulator. Students in VT-23 at Naval Air Station (NAS) Kingsville, Texas were exposed to demonstrations of carrier landings in the T-45 simulator prior to their carrier qualifications. A sister squadron at NAS Meridian, Mississippi (VT-19) did not receive exposure to the simulator. Both squadrons conducted carrier qualifications on the same dates and same aircraft carrier. A comparison of the squadrons considered the four measures of effectiveness (MOE): 1) squadron disqualification rates, 2) LSO trend analysis scores, 3) Aviation Training Form (ATF) CQ-11x performance evaluations, and 4) average grades for individual performance areas listed on ATF CQ-11x. Students in VT-23 had higher CQ-11x performance evaluations. When the performance evaluations are broken down to individual performance areas, VT-23 also has substantially higher grades in Pattern. Allowing for the importance that a proper flight pattern has on the approach and landing on the aircraft carrier, it is argued that exposure to the T-45 visual simulator had a positive effect on the students in VT-23.

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EXECUTIVE SUMMARY

With the introduction of a new training jet, the T-45A Goshawk, the Navy is introducing an entirely new training program. The T-45 training program is heavily computerized, emphasizing computer based training and a state-of-the-art, visual, dome simulator. When Hughes designed the new training jet, they designed more than just an aircraft, they designed an entire training system, including classroom lectures, computer based training, and two highly advanced, state-of-the-art simulators. The most advanced of these flight simulators introduces visual simulation into the training pipeline.

The T-45 Operational Flight Training (OFT) simulator is built around a replica of a Goshawk cockpit. The visual simulation is projected onto a partial dome screen, allowing the student a 180 degree horizontal and 60 degree vertical field of view. The three areas in the training curriculum that require the greatest use of the Student Naval Aviator's (SNA) visual skills are landing skills, weapons training and carrier qualifications. The visual system allows extensive training in all of these areas. For weapons training, the simulator includes air/ground bomb, racket and strafing models, rocket models, and the dust puffs of ordnance exploding on the ground at the impact points. For landing skills, several highly detailed models of Naval Air Stations, outlying fields and Air Force Bases are also modeled. Finally, for carrier operations, a dynamic model of the aircraft carrier USS Nimitz is provided. In the simulator, the SNA can experience carrier deck arrested landings, on deck taxiing, and catapult takeoffs in sea states from zero to sea state five. Rain, fog, cloud cover, sea state, and turbulence can be introduced, modified, or dismissed by simple instructor-computer interface controls in order to provide a more realistic aircraft flight deck environment.

Such innovation in training, not to mention the cost of such innovation, begs the question of effectiveness. How effective is the training program? How effective is the visual simulator over the standard instrument simulators? The U.S. Navy Jet Undergraduate Training Program (JUTP) is conducted in two locations, Meridian, Mississippi (VT-19) and Kingsville, Texas (VT-23). The T-45 visual-dome simulator was installed in Kingsville in 1990. From 1990 to 1993 the T-45 Goshawk was not ready for

students. Instructor training for the T-45 began in the summer of 1993 and students started actual T-45 flights nearly a year later. However, while the simulator waited in Kingsville, T-2C Buckeye students were exposed to demonstrations in the flight simulator prior to their carrier qualifications and weapons training. The T-2C students in Meridian did not receive visual simulator exposure. By comparing these two groups in Meridian and Kingsville it may be possible to quantify and hopefully analyze the effectiveness of the new visual simulator.

Sixty-nine students from VT-19 and 67 students from VT-23 were reviewed for this study. Both squadrons conducted carrier qualifications on the same dates and same aircraft carrier during May and July of 1993. VT-19 used five different Landing Signal Officers (LSO) over this period. VT-23 used seven different LSO's. Measures of effectiveness (MOE) for the comparison were 1) squadron disqualification rates, 2) LSO trend analysis scores, 3) Aviation Training Form (ATF) CQ-11x average performance evaluations, and 4) average grades for individual performance areas listed on ATF CQ-11x. The MOE's were evaluated using a regression model that tested for squadron, month, LSO, and interaction effects.

The resulting analyses indicate that there was no difference between the squadrons in disqualification rates and LSO trend analysis scores. A significant difference exists in the CQ-11x average performance evaluations. VT-23 appears to have a higher average, albeit over a very small range. When the average performance evaluations are broken down to individual performance areas, the difference between the squadrons is more acute. VT-23 has substantially higher grades in Pattern, and moderately higher grades in Start Position, Power Control, and Glideslope Control. Ruling out possible effects due to differences in the LSO's, the Pattern grade remains as the most significant difference between the squadrons.

While it must be argued that the measures of effectiveness considered are subjective measures of human evaluation, the importance that a proper pattern has on the entire carrier landing process cannot be argued. Although students are taught to make most of their turns during the landing pattern using the cockpit instruments, they are also encouraged to use visual landmarks on the ground while learning the approach. These

visual aids are not available to the student during a carrier approach, and while the student is constantly reminded of this fact, it must certainly be disorientating during the first few approaches to the ship. One advantage of the T-45 visual simulator, may be an awareness of this spatial disorientation. In the simulator, the student is given an opportunity to observe the relatively small deck of a carrier against a massive, featureless ocean, and has the opportunity to witness a simulated instrument approach to the carrier. Such awareness may encourage students to place more emphasis on their pattern, thus resulting in higher grades.

Due to the limited nature of this study, it is imprudent to make a blanket statement about the effectiveness of the T-45 visual simulator. However, although further study is warranted, the simulator appears to have a positive effect on student's ability to recognize and fly the proper pattern as they approach the aircraft carrier.

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I. INTRODUCTION

A. A BRIEF HISTORY OF THE USE OF SIMULATORS IN AVIATION

Since the inception of flight, the aviation community has looked for better, safer methods to train new pilots with minimal loss of students and aircraft. Flight simulators allow an instructor to present many of the skills required to control an aircraft while the student is still on the ground. Simulator use is recorded as early as 1910 in the United States, Britain, and Italy, an indication of the importance of this new form of training. Early simulators were actual modified aircraft mounted on universal joints that, under proper wind conditions, allowed the student to control for air turbulence. Other inventors engineered manual levers for the instructor to manipulate the simulator's movements. The common technique stressed by these early simulators was movement--the students ability to manually control the aircraft.

In 1929, Edwin Link designed a pneumatically controlled simulator. Link's simulator still required pitch, roll, and yaw movements to be initiated manually, but then used a pneumatic bellows to fine tune the movement. The Link simulator was announced to have simulated the true feel of flying without ever leaving the ground. (Rolfe and Staples 1986, 19-20). But just as Link's patent cleared, flight simulation began to take another direction. Instructors began to realize that simulator motion was not an effective training aid. As aircraft became more involved, instruments were installed on the simulators to mimic the flight controls on the more modern aircraft. Simulators proved to be excellent instrument trainers, an important task that they still perform today.

By the beginning of World War II, military air corps in Europe, the United States, and Japan were conducting basic instrument training in Link simulators. During World War II, simulators were used for much more than training new pilots. Simulators were modified to enhance celestial navigation and bombing skills. World War II also saw

simulators being adapted to train for specific types of aircraft. By the end of World War II, the aviation world realized that they depended more on the simulator's instrument capabilities and less on the movement of the simulator. Post World War II development stressed electronic and analog instrument trainers as the flight simulator's primary mission.

Today, flight simulators come in many forms, from simple static cockpits that allow pilots to practice ejection techniques to the most advanced F/A-18 trainer that incorporates motion, pressure suits and 360-degree visual, dome simulation. With the advances in computer generated graphics, visual flight simulators provide a degree of reality never before experienced in flight simulation. A pilot can now experience the feeling of three-dimensional flight without ever leaving the ground.

B. THE SIMULATOR AND U.S. NAVAL AVIATION TRAINING

Throughout the development of flight simulation, the military has been at the forefront in its support and use of the technology. The military realized the potential of the aircraft's fighting capability during World War I. At this time, the military also recognized the need for rapidly teaching flying skills to large numbers of men (Rolfe and Staples 1986, 16). While simulators were not used extensively during World War I, the need to optimize training resources and student qualification inspired the development of the discipline of Aviation Psychology. Aviation Psychology would not only develop guidelines for the military's selection of recruits for flight training, but advise the engineers who built the simulators used in their training.

During World War II, the U.S. Navy trained with a simulator built by Bell Laboratories (Rolfe and Staples 1986, 28). The Bell Laboratories simulator consisted of a PBM-3 front fuselage and cockpit, with complete controls, instrumentation and auxiliary equipment, and even included a computing device to solve flight equations. The PBM-3 simulator is credited as the first operational flight trainer that attempted to simulate the characteristics of a particular aircraft.

Today the United States Navy has a flight simulator for every aviation platform it flies. In addition to real flight hours, pilots are required to fly simulated flights on a

regular basis. Student pilots begin using flight simulators in basic flight school and continue into their specialized training in either the Strike (Jet), Fixed Wing, or Rotor communities. In the flight training pipeline, instrument training is stressed. Most pilots do not fly a visual simulator until they complete their training program and report to their first squadron.

1. U.S. Navy Jet Undergraduate Training Program (JUTP)

In the past, the training pipeline for jet pilots consisted of three distinct stages using three different aircraft. The Primary stage was common to naval aviators, basic flight training in the twin turbo-prop T-34. Once basic flight training was completed, SNA's assigned to the jet training pipeline began the Intermediate stage of their instruction. The Intermediate stage used the T-2C Buckeye aircraft. This stage lasted for approximately 8 months and concluded with initial carrier qualification. From the Intermediate stage the Student Naval Aviator (SNA) progressed to the Advanced stage and yet another aircraft, this time the A-4 Skyhawk. In the Skyhawk, the SNA practiced many of the skills learned previously in the T-2C. Upon completion of the Advanced stage, usually about 10 months, the student qualified for carrier landings for the second time. Successful completion of all three stages certified the SNA as fully qualified, "winged" Navy jet pilot. The SNA was assigned to a specific Navy platform (F-16, A-6, F/A-18) and transferred to that aircraft's Fleet Readiness Squadron (FRS). While training simulators of all types were used in the Jet pipeline, the simulators stressed instrument work and provided no visual simulation.

2. T-45 Goshawk Training Program

With the introduction of a new training jet, the T-45A Goshawk, the Navy is introducing an entirely new training program. The T-45 training program is heavily computerized, emphasizing computer based training and a state-of-the-art, visual, dome simulator. The T-45A Goshawk aircraft was designed to eliminate the Intermediate stage of the jet training pipeline. New SNA's will now fly only one platform after their Primary Stage. The T-45 curriculum is designed to last approximately 1 year and covers all of the skills taught in the original training pipeline, with one important difference, only

one carrier qualification is now required. When Hughes designed the new training jet, they designed more than just an aircraft, they designed an entire training system, including classroom lecture, computer based training, and two highly advanced, state-of-the-art simulators. The most advanced of these flight simulators introduces visual simulation into the training pipeline.

The T-45 Operational Flight Training (OFT) simulator is built around a replica of a Goshawk cockpit. A Gould SEL 32/8780 computer with 2M bytes of memory controls the simulation scenario. While anchored to a fixed platform, the simulator uses G-seat/G-motion cueing systems and an aural system to provide realistic aircraft motion, audio and aerodynamic cues. The visual simulation is projected onto a partial dome screen, allowing the student a 180 degree horizontal and 60 degree vertical field of view. The three areas in the training curriculum that require the greatest use of the SNA's visual skills are landing skills, weapons training and carrier qualifications. The visual system allows extensive training in all of these areas. For weapons training, the simulator includes air/ground bomb, racket and strafing models, rocket models, and the dust puffs of ordnance exploding on the ground at the impact points. For landing skills, several highly detailed models of Naval Air Stations, outlying fields and Air Force Bases are also modeled. Finally, for carrier operations, a dynamic model of the aircraft carrier USS NIMITZ is provided. In the simulator, the SNA can experience carrier deck arrested landings, on deck taxiing, and catapult takeoffs in sea states from zero to sea state five. Rain, fog, cloud cover, sea state, and turbulence can be introduced, modified, or dismissed by simple instructor-computer interface controls in order to provide a more realistic aircraft flight deck environment (T-45A Simulator Training System Overview, 1-3 - 1-4).

C. VISUAL SIMULATOR EFFECTIVENESS

The training effectiveness of visual dome simulators is hard to measure. One means of measuring simulator effectiveness is through transfer of training: the ability of the student to transfer what he has practiced in the simulator to the actual aircraft (Lintern et al. 1990, 320). But the skills trained in a simulator are controlled and constrained by

the simulator's characteristics. These characteristics include realism of the cockpit and instrument panel, realism of motion effects, and in the case of visual simulators, realism of the visual system.

Even if transfer of training is verified, singling out the individual role played by a simulator characteristic can be difficult. At the University of Illinois, researchers found that beginning flight students were positively affected by visual simulator landing practice prior to solo landings in actual aircraft (Lintern et al. 1990, 324). While this study indicates that visual simulators have a positive training effect, how much of the training transfer can be attributed to the simulator's visual system is hard to measure. Student motivation and the additional training with similar controls may also contribute to the improved flight performance (Gopher et al. 1994, 401). In an attempt to isolate the effect of a visual system, various studies have examined how much visual acuity is required to achieve a transfer of training. Detail and field of view may also play an important part in the transfer of training. Density, or the visual definition of a simulated object, appears to be more important than the visual detail of the object (Kleiss and Hubbard 1993, 653). Concurrent with the development of the T-45 simulator and training program, D. P. Westra and colleagues conducted a study for the Naval Training Systems Center in Orlando, Florida (Westra et al. 1985). The Westra study provided key recommendations for the design of carrier landing tasks for the T-45 visual simulator. In the study one group of SNA's received training in an experimental visual simulator and were compared against a control group of SNA's who did not receive training in the simulator. Special equipment was developed to measure aircraft deviations as the student approached the landing field. Westra's study is important because it identified a measurable improvement in Flight Carrier Landing Practice (FCLP) performance when student pilots practiced with the simulator. However, Westra did not extend his research to the deck of an actual carrier because of difficulties with stabilizing his equipment on a rolling deck.

D. PROBLEM STATEMENT

The U.S. Navy JUTP is conducted in two locations, Meridian, Mississippi and Kingsville, Texas. The T-45 visual-dome simulator was installed in Kingsville in 1990. From 1990 to 1993 the T-45A Goshawk was not ready for students. Instructor training for the T-45A began in the summer of 1993 and students started actual T-45A flights nearly a year later. However, while the simulator waited in Kingsville, T-2C Buckeye students were exposed to demonstrations of the flight simulator prior to their carrier qualifications and weapons training. The T-2C students in Meridian did not receive visual simulator exposure. By comparing these two groups in Meridian and Kingsville, this study attempts to quantify and analyze the effectiveness of the new visual simulator. Chapter II describes in detail carrier qualification requirements, the data, and the measures of effectiveness used for the study. The results of the data analysis are presented in Chapter III. Discussion of the results and conclusions of the study are addressed in Chapters IV and V, respectively.

II. METHODOLOGY

A. CARRIER QUALIFICATION REQUIREMENTS

Student Naval Aviators reviewed for this thesis were in the intermediate phase of their strike flight training. Previous training included basic ground school and basic flight skills in the T-34 turbo prop training aircraft. Students receive carrier qualification instruction as the last section of their intermediate syllabus. Previous sections in the syllabus include Familiarization, Basic Instruments, Radio Instruments, Airways Navigation, Basic Formation, Night Fly, Gunnery/Weapons, and Out of Control Flight.

1. Field Carrier Landing Practice (FCLP)

During carrier qualification training, the student receives 11 periods of instruction which are coded CQ-1 through CQ-11x. CQ-1 begins with a basic review of procedures and flight skills to allow both the student and the instructor to adapt to each other. The student is assigned to the same instructor throughout the CQ stage. The instructor is a qualified Landing Signal Officer (LSO) trained and certified to assist pilots as they approach and land on the deck of a carrier. During CQ-1 through CQ-10, the student flies Field Carrier Landing Practice (FCLP) landings on an air strip, which is painted to resemble the deck of an aircraft carrier. A Fresnel Lens Optical Landing System (FLOLS), identical to the FLOLS on a carrier, is used to help the student line up properly.[1] The instructor/LSO guides the student to the airstrip using the same directions that will be used on the aircraft carrier. At the end of CQ-1, CQ-2, CQ-9, and CQ-10, the student is evaluated by his instructor using an Aviation Training Form (ATF). A grade is assigned based, in part, on an evaluation of the student's headwork, airwork, start position, line up, and speed control. A full listing of the performance areas considered on these ATF's is presented in Appendix A. Grades are given on a four point interval scale with 1 = unsatisfactory, 2 = below average, 3 = average, 4 = above average. The

[1] The FLOLS is sometimes referred to as the glideslope indicator or in pilot vernacular "the ball".

points are summed and averaged for a final ATF score. At the end of CQ-10, the student is evaluated for field qualification. If field qualification is granted, the student advances to CQ-11, which includes the actual carrier landing.

2. Carrier Qualification

For his carrier qualification, the Student Naval Aviator receives two numeric grades, an overall flight performance grade and a LSO trend analysis grade of his actual approaches and arrests on the carrier deck. The LSO/instructor evaluates the Student Naval Aviator's performance in nineteen areas listed on the Aviation Training Form (ATF) for CQ-11 as either Unsatisfactory, Below Average, Average, and Above Average. While the LSO's evaluation of these performance areas is subjective, his own flight experience as well as standardized instructor training, lend validity to the assigned grade.

In addition to the specific items listed on the CQ ATF, the LSO must also consider the following criteria for qualification:

- Student displays no dangerous tendencies.
- Student demonstrates steady or improved performance during FCLP/ship qualification period.
- Student requires minimum LSO assistance during the final two approaches/landings.
- Student is predictable-ready for Advanced Strike.
- Student has a 50 percent or better boarding rate (Chief of Naval Air Training (CNATRA) CQ instruction 1994, III-3).

The second numerical grade is reported on the LSO Trend Analysis Sheet. Every pass and approach that a Student Naval Aviator makes on the carrier is graded by his LSO. This practice is continued even after the SNA completes his training and enters a Fleet Squadron. The student is required to make at least six approaches to the aircraft carrier; four of the approaches must be complete, arrested landings and two of the approaches must be touch and go landings. Each approach to the carrier is assigned a grade on a five point scale. Once again the grades are subjective but are based on the LSO's experience observing and waving other pilot approaches. Westra writes that

previous research has identified four factors that the LSO considers when assigning the trend analysis scores. These four factors, in order of importance are: 1) touchdown accuracy, 2) approach glideslope control, 3) approach lineup control, and 4) approach angle of attack control (Westra et al. 1985, 41). The LSO marks and grades are listed in Appendix B. The minimum grade acceptable for the LSO Trend Analysis is 2.4. Qualification of students with less than 2.4 may be given in special cases, but only if the student demonstrates an overall improving trend. Additionally, a student with 2.4 or better may be disqualified for not meeting any of the criteria scored on the ATF.

B. DATA DESCRIPTION

Data were collected for SNA's at the CNATRA archives at Naval Air Station (NAS) Corpus Christi, Texas for the carrier qualification periods in May and July of 1993.

1. Boat Detachment Dates

Carrier qualification flights were conducted between May 14-19 and July 23-27, 1993. USS AMERICA (CV 66) and USS JOHN F. KENNEDY (CV 67) were the designated carriers for May and July, respectively. Both carriers were located off the eastern coast of Florida. Students and their instructors flew their aircraft from Key West, Florida and met the carriers at sea. The weather during these qualification periods appeared mostly mild, with sea state ranging from 1/2 to 2 meters, winds 5-22 knots, and a cloud ceiling averaging around 3500 feet (Fleet Numeric Meteorological and Oceanographic Center, 1993). A summary listing of the weather conditions is provided in Appendix C.

2. Training Squadrons

a. VT-19, NAS Meridian, Mississippi

The students at VT-19 did not receive exposure to the T-45 simulator. Student scores from the May and July carrier qualification periods of 1993 were analyzed. Of the 79 students who participated in the two Carrier Qualification periods, 69 student records were available for examination.

b. VT-23, NAS Kingsville, Texas

Documentation indicates that 75 T-2 students in Kingsville received exposure to the T-45 simulator prior to their carrier qualifications during two separate carrier qualification periods in May and July of 1993. Exposure to the simulator consisted of a 90 minute demonstration of carrier approaches, arrests, and touch and goes. Each student sat in the cockpit of the simulator for approximately 5-10 minutes and observed the aircraft fly from approximately three miles aft of the carrier, through the approach pattern, to the deck for a touch and go, and back around the pattern again for an actual arrested landing. Students did not actually fly the simulator because the controls did not match those of the A-4, but the students could hold the stick and feel the aircraft movements and power adjustments. The instructor monitoring the demonstration could stop the simulation at any time for questions or observations. Sixty-seven student records were available. A breakdown of the number of students from each carrier qualification period and squadron is listed in Table 1.

Table 1: Number of students participating during each carrier qualification versus number of students reviewed.

Squadron	Month	Total Students Present	Number Reviewed	Percentage Reviewed
VT-19	May	40	37	92.5
VT-23	May	43	41	95.3
VT-19	July	39	32	82.1
VT-23	July	32	26	81.3

3. The Landing Signal Officer (LSO)

For their carrier qualification instruction, students are assigned to a Landing Signal Officer (LSO), a pilot certified to provide directions to other pilots during their carrier approach and landing. LSO's are trained in accordance with the LSO NATOPS. While assigned to his/her first squadron, a pilot may begin the LSO qualification process. First

the pilot attends a three week LSO school in Oceana, Virginia. Upon completion of the school, the pilot returns to his squadron and begins an on-the-job-training qualification process, beginning with the Field Qualification. The Field Qualification allows the pilot to direct other pilots flying his own type of aircraft to land on an airfield when a fully qualified LSO is present. The second qualification, the Squadron Qualification, allows the pilot to land any type of aircraft on the deck of an aircraft carrier during periods of good weather. The final qualification, the Wing Qualification, permits the pilot to land any aircraft on the deck of an aircraft carrier, during day or night. When the pilot transfers from the squadron to a training squadron, he/she must be either Squadron or Wing Qualified as an LSO. The pilot attends a three day refresher LSO school and must attend at least three carrier qualification periods before being designated Training LSO.

In the training squadron, the LSO instructs, evaluates, and grades the student through out the entire carrier qualification period. Should a student disqualify during the carrier qualification period, he is reassigned to a new LSO and must repeat all previous carrier qualification lessons. The students examined in this study were graded by 12 different LSO's, 5 LSO's from VT-19 and 7 LSO's from VT-23. A breakdown of the LSO's and the number of their students reviewed are listed in Table 2. To protect confidentiality, LSO's are referred to alphabetically.

C. MEASURES OF EFFECTIVENESS

In comparing the two squadrons, VT-19 and VT-23, several measures of effectiveness (MOE) were used to determine if the T-45 visual simulator had an effect on SNA carrier qualification. The first MOE looked at the percentage of disqualifications within each squadron. The second MOE examined the final LSO Trend Analysis grade for each SNA. The third MOE examined the final ATF performance evaluation for each SNA. Finally, the CQ-llx ATF was broken down into its separate 19 performance areas to determine if there was a difference in certain areas of flight performance.

Table 2: LSO breakdown by squadron and carrier qualification period.

LSO	Squadron		Month		Number of Students	
	VT-19	VT-23	May	July	May	July
A	X		X	X	7	9
B	X		X	X	8	10
C	X		X	X	7	4
D	X		X		7	
E	X		X	X	8	9
F		X	X	X	9	4
G		X	X	X	6	5
H		X	X	X	9	4
I		X	X	X	9	3
J		X	X		8	
K		X		X		5
L		X		X		5

III. RESULTS

A. COMPARISON OF DISQUALIFICATION RATES

Table 3 presents the number of disqualifications (DQ) per squadron during each carrier qualification period.

Table 3: Disqualification rates by squadron and carrier qualification period.

Squadron	May			July		
	Number Qualified	Number Disqualified	Percent Disqualified	Number Qualified	Number Disqualified	Percent Disqualified
VT-19	40	4	10.0	36	2	5.2
VT-23	49	3	7.0	29	3	9.3

To compare the two squadrons, a two by two contingency table was developed by counting the number of disqualifications and qualifications within each squadron during a particular qualification period. A contingency table is used to count the number of occurrences and compare that count to the expected number of occurrences based on the assumption that the DQ rate is the same for both groups. The difference between the actual and expected occurrences is used to generate a chi-square number. Large chi-square values indicate large differences between the actual and expected occurrences. For this comparison, four two by two contingency tables were used. Two tables were used to test the hypothesis that the number of disqualifications was independent of the squadron during the qualifications periods of May (Table I) and July (Table II). The two remaining tables were used to test the hypothesis that the number of disqualifications was independent of the qualification period for VT-19 (Table III) and VT-23 (Table IV). The final contingency table (Table V) pools squadrons and qualification period together into a two by four table, again testing for independence in the number of disqualifications. Table 4 lists the results of the five contingency tables. Judging from the very low chi-square values and corresponding high p-values, there is no evidence to say that the

number of disqualifications is independent of squadron and carrier qualification month. The squadrons appear to disqualify equal number of students. Complete contingency tables are presented in Appendix D.

Table 4: Contingency Table results for comparison of disqualification (DQ) counts.

Contingency Table	Tested for Independence	DF	Chi-Square	p<
I	May DQ's	1	0.131	0.7174
II	July DQ's	1	0.443	0.5057
III	VT-19 DQ's	1	0.441	0.5066
IV	VT-23 DQ's	1	0.143	0.7053
V	All DQ's	3	0.786	0.8528

B. COMPARISON OF LSO TREND ANALYSIS SCORES

The LSO evaluates every approach the student flies on the carrier using a seven point scale labelled from zero to five, where zero indicates a cut or an unsafe pass and five indicates a perfect pass. Table 5 lists the grading scale used by the LSO for the carrier approach evaluation. Students are required to make at least six passes (four arrests and two touch and gos). At the end of the qualification period the student's approach grades are averaged to two decimal places to form the student's LSO Trend Analysis Score. Four of the students reviewed for this study did not have a complete LSO Trend Analysis form in their training record. Their LSO Trend Analysis records are not reviewed in the following comparison.

Table 5: LSO Trend Analysis grading scale

Symbol	Definition	Grade
OK	Perfect pass.	5
OK	Reasonable devations with good corrections.	4
(OK)	Fair, reasonable deviations.	3
B	Bolter.	2.5
-	Below average but safe pass.	2
PWO	Power waveoff	2
OWO	Own waveoff.	2
WO	Waveoff	1
C	Cut. Unsafe, Gross deviations made inside waveoff window.	0

The LSO's from a given squadron graded only students from that squadron. Additionally, each student was graded by the same LSO during the entire carrier qualification process. Because 12 different LSO's graded students during this time period, consideration must be given to individual grading differences between the LSO's. Table 6 presents the breakdown of the LSO's used during a qualification period by squadron. Note that not all the LSO's grading in May, graded in July. Likewise additional LSO's were present in July who did not grade in May. In constructing a model for comparison of the two squadrons, it is necessary to make assumptions about the LSO's employed in grading SNA's. The analyses presented are essentially based on the concept of a pool of trained LSO's, any of whom might be assigned to a particular squadron (and set of students).

Table 6: Breakdown of LSO's used by each squadron during a particular qualification period.

Squadron	VT-19	VT-23	*Month Total*
May LSO's	A, B, C, D, E	F,G,H,I,J	*10*
July LSO's	A,B,C,E	F,G,H,I,K,L	*10*
Squadron Total	*5*	*7*	

Figure 1 presents box plots for the LSO trend analysis scores given by individual LSO's during May and July qualification periods. The box plots in this graph present important information on the distribution of the LSO's trend analysis scores. The top and bottom line of the box represent the first and third quartiles of the range for the LSO's trend analysis grades. Fifty percent of the data is located within the box. The line within the box is the median trend analysis score given by that LSO. In some cases, the LSO gave the same grade to several students and the median trend analysis score may be located on the top or bottom of the box. Median values are labeled on the boxes to aid in their recognition. Lines extending from either end of the box indicate the shape of the distribution's tail. Long lines indicate a stretched distribution, short lines indicate

compactness and bunched data. Asterisks represent outliers, data points that differ significantly from the rest of the data (Chambers et al. 1983, 22). The width of each box plot is proportional to the square root of the sample size of the data used to plot the box. To aid in the interpretation of sample size, the actual sample size appears as a number beneath each box plot.

As can be seen from Figure 1, there appears to be very little difference in the median trend analysis score given by the LSO's during the May qualification period. Medians range from approximately 2.43 for LSO C to 2.81 for LSO J. The relatively short median range of 0.38 indicates little variance between the LSO's. However, VT-19 has three low outliers and VT-23 has a one low and one high outlier. In all cases, a low outlier corresponds to a student who ultimately was disqualified during that qualification period. The minimum and maximum median for July are 2.5 for LSO's E, F, and I and 2.65 for LSO L. Both bounds occur for LSO's in VT-23. However, the range of medians in July is considerably smaller than the range of medians in May, 0.15 vice 0.31. The lack of outliers in July is probably due to the data reviewed rather than an actual grading difference. Students who disqualified in July were given a second opportunity to qualify in September. Records were not reviewed for September, hence the July LSO Trend Analysis Sheet recording the disqualification were not reviewed as well.

When the trend analysis scores are combined across both qualification periods, Figure 2 results. Figure 2 illustrates the trend analysis scores for the LSO's. The median range extends from 2.44 to 2.81. VT-23 has two additional outliers, one high and one low, for a total of four outliers. VT-19 still has the three low outliers. For the most part however, there appears to be little variance in the LSO's grading procedures. This observation can be seen more clearly in Figure 3, which presents box plots of the squadron's trend analysis scores over both qualification periods. Even with the presence of the low outliers in VT-19, the box plots are remarkably similar. The overall median trend analysis score for the two squadrons is only .01. As indicated by the above figures, there appears to be little difference in the LSO trend analysis scores in VT-19 and V-23.

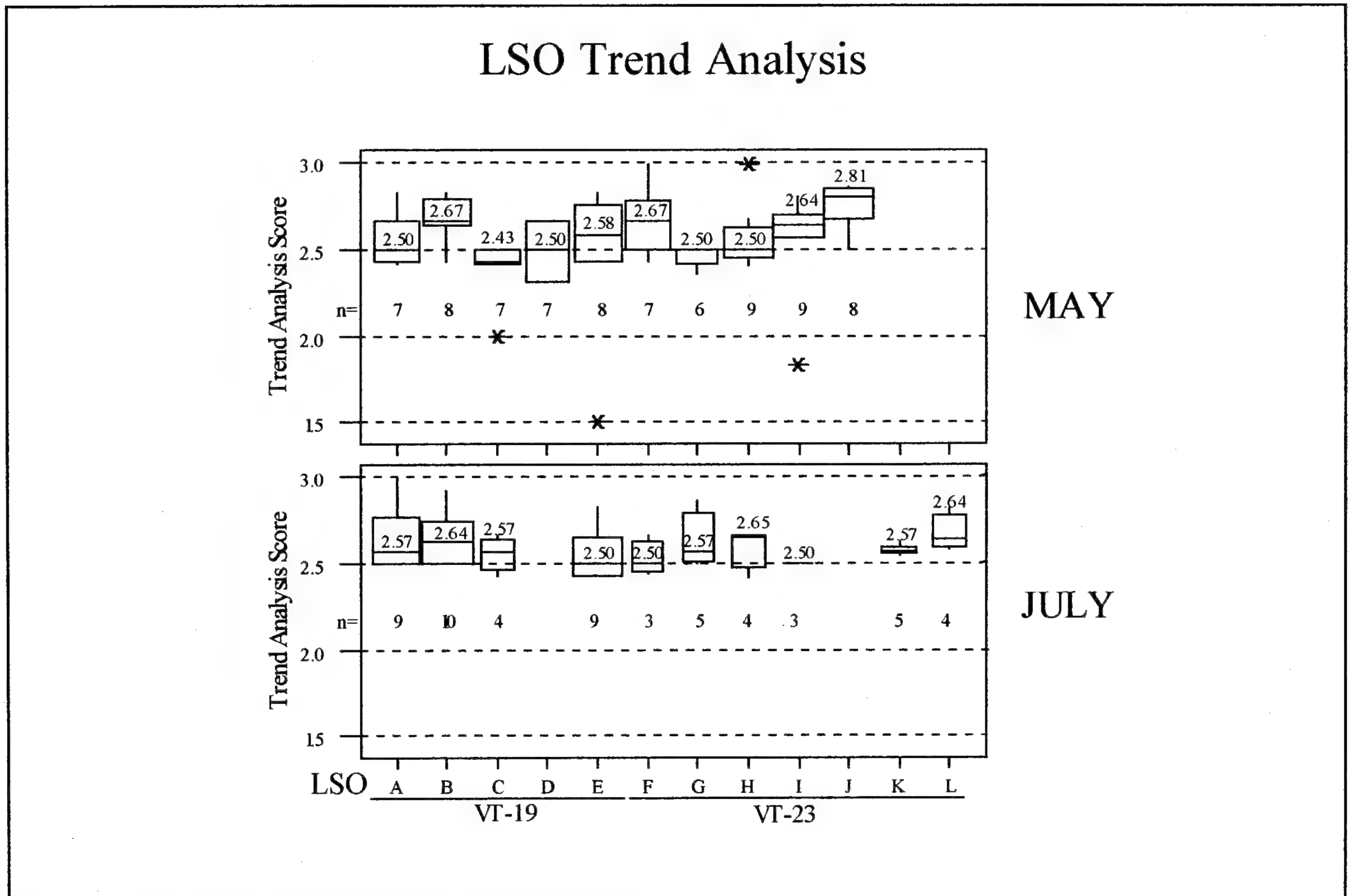

Figure 1: Box Plots of LSO Trend Anlaysis Scores

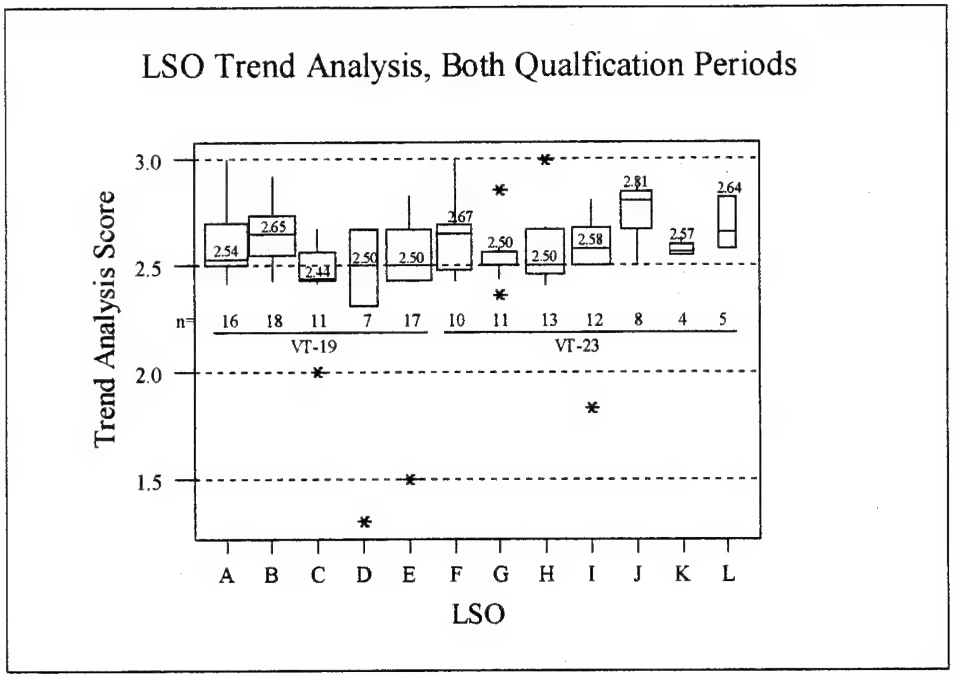

Figure 2: Box Plots of LSO Trend Anlaysis Scores, Both Qualification Periods.

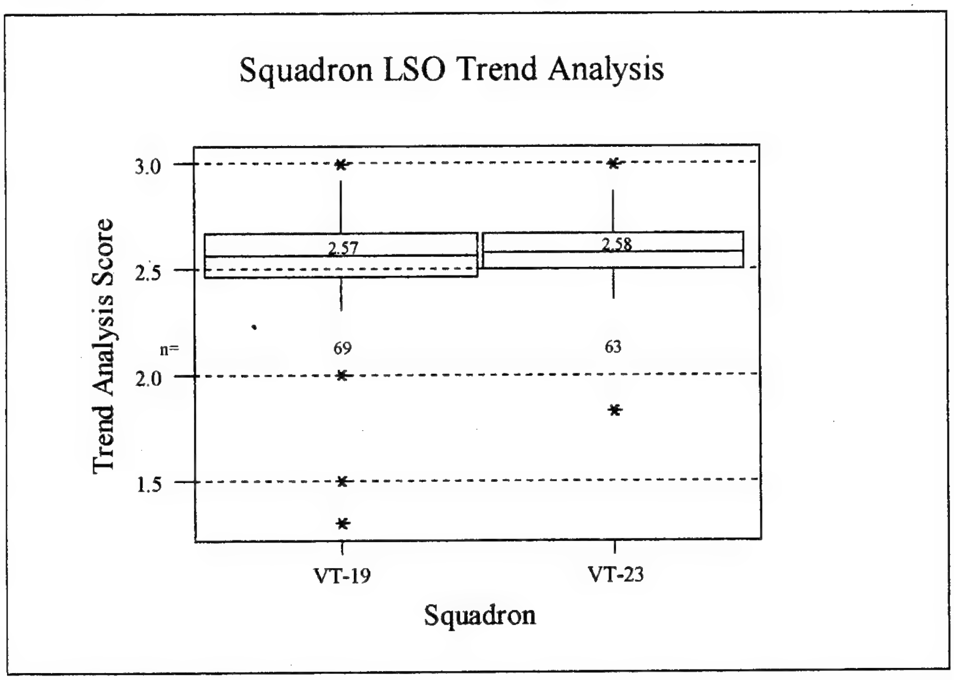

Figure 3: Box Plots of Squadron LSO Trend Analysis Scores, Both qualification periods.

To quantify the box plot comparisons, an Analysis of Variance (ANOVA) was conducted to test for significant differences between the squadrons. An ANOVA can be used to test for the equality of two or more means that come from independent, normal populations with equal variances. It should be noted however, that the primary use of an ANOVA is to model data from a designed experiment in which certain factors are controlled while others vary. As the data for this study is historical, the ANOVA model may oversimplify any relationships in the data.

As mentioned earlier, the particular LSO's assigned to a given squadron at a given time have received the same training and are selected haphazardly, with no special purpose. (The same is true of the student aviators.) The statistical model employed for the following ANOVA discussions is aimed at identifying possible differences between the two squadrons undergoing carrier qualification; any identified difference may then be attributed to the use of the simulator. The individual trend analysis score received by any student is assumed to be an accumulation of effects of (a) the squadron trained in (simulator or no simulator), (b) the month of qualification (May or July), (c) possible interaction between squadron and month, and (d) the particular LSO grading the given student. In statistical jargon, the squadron and month contributions are fixed effects, while the LSO's are random effects and nested within squadrons. An implication of these assumptions then is that (possible) differences in the fixed effects are judged relative to the variability between the LSO's within the squadron (as opposed to the variability within scores issued by the same LSO).

The currently available statistical packages do not allow for nested factors with varying numbers of levels (in May 5 LSO's were used in each squadron, while in July there were 4 LSO's used by VT-19 and 6 LSO's used by VT-23). The ANOVA results in Table 7 were computed in APL and (partially) verified by the MINITAB® program. The complete model is presented in Appendix E.

The results confirm the prediction of the box plots. Squadron and qualification period have no significant effect on the LSO trend analysis scores. The hypothesis that the mean trend analysis scores are equal between the squadrons and qualification period cannot be rejected. Likewise, there appears to be no significant interaction between the squadrons and qualification period. While there does appear to be some variance between the LSO's within a squadron, the variance is not statistically significant with $\alpha = 0.05$. If the exposure to the visual simulator had any effect on the students in VT-23, its effects are not apparent in the the trend analysis scores.

Table 7: ANOVA Results for LSO Trend Analysis Scores.

Effect	DF	Sum Squares	Mean Squares	F-value	p-value
Squadron	1	0.1943*	0.1943	2.41	0.151
Qualification Period	1	0.0310*	0.0310	0.39	0.549
Interaction	1	0.0246*	0.0246	0.31	0.592
LSO Variance	10	0.8049*	0.08049	1.72	0.066
Error	118	5.2556	0.0454		
Total	131	6.4548			
		*Adjusted			

C. COMPARISON OF LSO PERFORMANCE EVALUATION

In addition to the Trend Analysis, the LSO also grades the student on 19 different performance areas listed on ATF CQ-11x. These performance areas consist of headwork, procedure, airwork, pattern, start position, speed control, attitude control, power control, line up, glideslope control, error detection/correction, waveoff technique, touch and go/bolter technique, response to LSO, formation/pattern entry, radio procedures, fuel management, deck procedures, and catapult procedures. Each of these 19 areas receives a mark of unsatisfactory, below average, average, or above average. The marks are then converted to an ordinal scale with "1" at unsatisfactory and "4" at above average. The LSO performance evaluation is the average of the grades assigned to the 19 performance areas. LSO performance evaluations will be compared in a similar manner to the LSO trend analysis scores.

Figure 4 presents box plots for the LSO performance evaluations given by individual LSO's during May and July qualification periods.[2] During the May qualification period, it is readily apparent that the LSO's in VT-19 gave lower performance evaluations than the LSO's in VT-23. The range of the median is 2.89 to 3.05, with the low median in VT-19 and the high median in VT-23. Within the squadrons, both VT-19 and VT-23 have a median range of 0.105. Such a small range seems to indicate little difference between the individual LSO's. Of the ten LSO's, five have a median of 3.0, yet another indication of similarity. However, the distribution of the performance evaluations across all LSO's and across the individual squadrons appear quite different. In spite of the five 3.0 medians, the majority of performance evaluations in VT-19 occur below 3.0 and the majority of performance evaluations in VT-23 occur above 3.0. The July qualification presents a similar picture. The range of the median extends from 2.95 to 3.05. Within the squadrons, there appears more similarity between the LSO's, both in their median performance evaluations and the distribution of the grades. Note that of the ten LSO's who graded during this period, six had median performance evaluations at 3.0. However, VT-19 still appears to have lower performance evaluations than VT-23. The majority of VT-19 performance evaluations occur below 3.0 and the two lowest medians occur in this squadron. VT-23 performance evaluation appear more equally distributed about 3.0. In fact of the six LSO's in VT-23, four have medians at 3.0, and the other two LSO's are split about the 3.0 mark.

The difference between the squadrons is more pronounced when the performance evaluations are examined over both qualification periods, as illustrated in Figure 5. The range of the median extends from 2.89 to 3.05. While a range of 0.16 seems relatively insignificant, the distribution of the grades, belies the small range. Seventy-five percent of the grades, for all LSO's in VT-19, are at or below 3.0. In VT-23, the grades are more appear more equally distributed about 3.0. Figure 6 presents box plots of the squadron

[2]Recall that two additional students were reviewed for this comparison. Hence, the sample sizes will not match the sample sizes for the May LSO Trend Analysis Comparison.

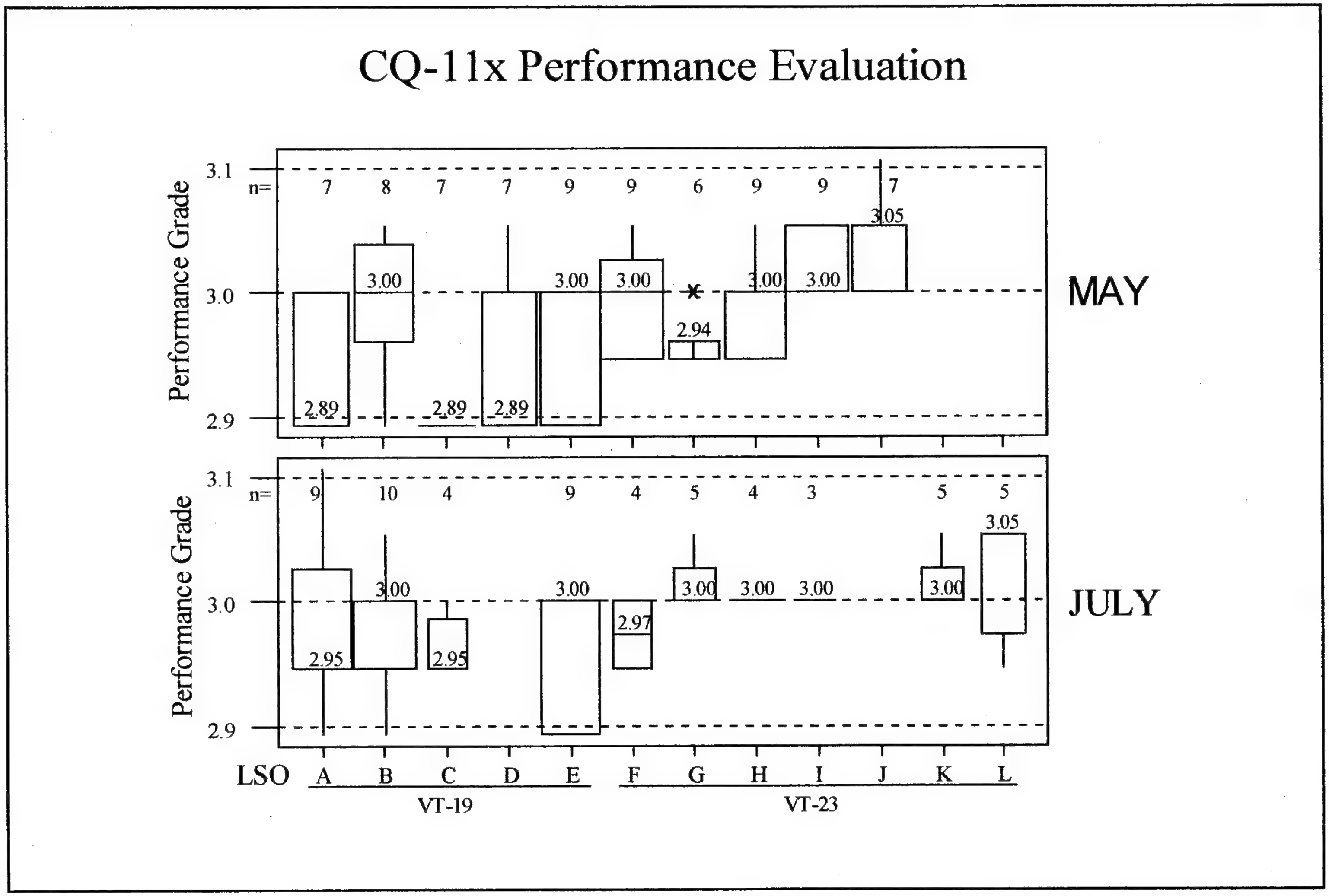

Figure 4: Box Plots of CQ-11x Average Performance Evaluations.

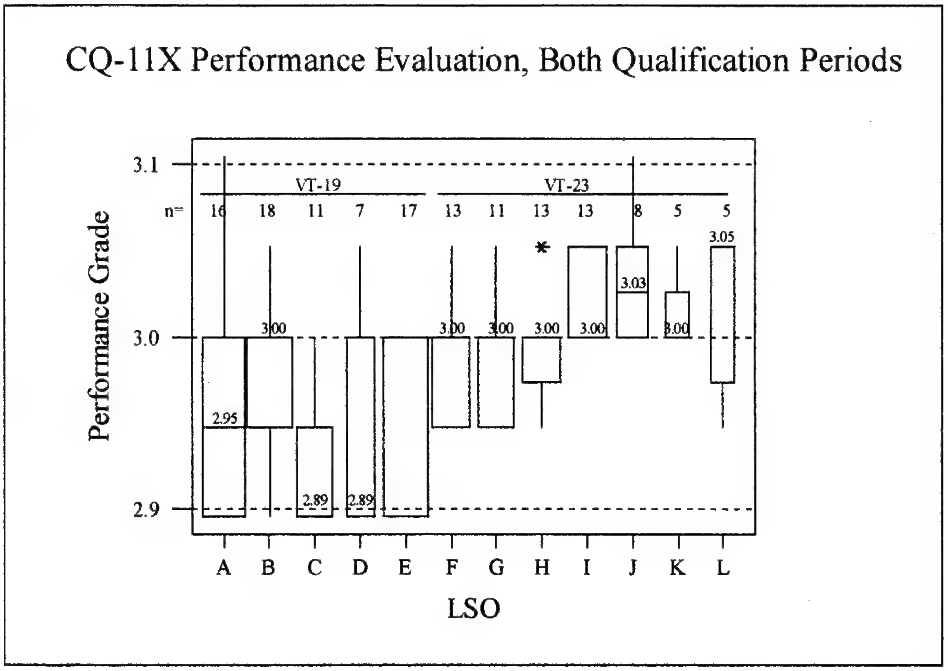

Figure 5: Box Plots of Individual LSO Performance Evaluations, Both qualification periods.

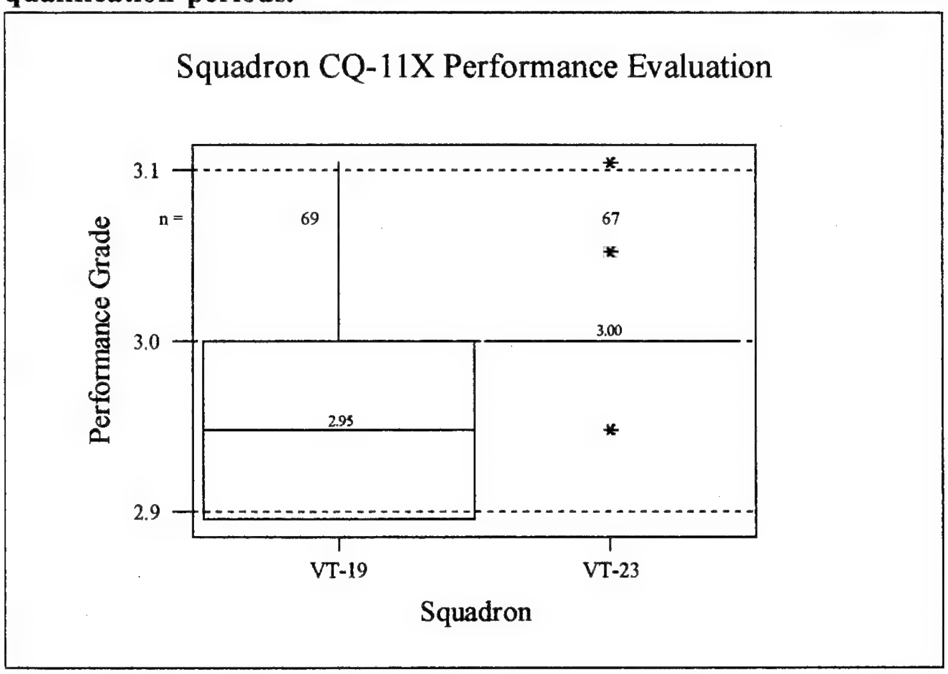

Figure 6: Box Plots of Squadron Performance Evaluations, Both qualification periods.

performance evaluations. The difference in this graph is even more pronounced. With the exception of the three outliers, all of the grades in VT-23 are at the median of 3.0.[3] The grades in VT-19 have greater variation and are centered on the median of 2.95. Figures 4-6 seem to indicate that there is difference in the CQ-11x performance evaluations between VT-19 and VT-23. Notably, students in VT-23 appear to have higher performance evaluations.

An ANOVA similar to the model used for the LSO trend analysis was developed to further examine the difference between the squadron performance evaluations. The hypothesis to be tested assumes that the mean performance evaluation is equal between the squadrons and qualification period and that there is no interaction between squadron and qualification period or extreme variance between the LSO's. Results of this analysis are presented in Table 8. As predicted by the box plots, there is a significant difference between the squadrons. However, there is no significant difference between the qualification periods nor is there any interaction between the squadrons qualification periods. Between the LSO's there is a significant difference in the variation of their grading procedures. Because the squadron's used their own LSO's, it impossible to

Table 8: ANOVA Results for CQ-11x Average Performance Evaluations.

Effect	DF	Sum Squares	Mean Squares	F-value	p-value
Squadron	1	0.0736*	0.0736	12.23	0.006
Qualification Period	1	0.0056*	0.0056	0.93	0.358
Interaction	1	0.0016*	0.0016	0.26	0.619
LSO Variance	10	0.0601*	0.0601	3.12	0.001
Error	122	0.2353	0.0019		
Total	136	0.3653			
		*Adjusted			

[3]While it appears that all but three performance evaluations is 3.0, the previous box plots have shown that this is not the case. The outliers in this graph correspond to more than one, and in most instances, several grades at 2.95, 3.05, and 2.10. However, as the vast majority of the grades in VT-23 were at 3.0, the distribution of the grades is unimodal to the extreme.

implicitly state that the difference in the performance evaluations was caused by the visual simulator. The difference may also be attributed to individual squadron differences and grading trends. Further examination of the performance evaluations is required.

D. COMPARISON OF INDIVIDUAL PERFORMANCE AREAS

Recall that the CQ-11x performance evaluation is the average of 19 separate performance areas. Figure 7 presents the average performance grade of both squadrons for each of the 19 areas evaluated on ATF CQ-11x. From the graph, VT-19 appears to have significantly lower performance scores in Pattern, Start Position, Power Control, Error Detection/Correction and Glideslope Control, and significantly higher performance scores in Waveoff Technique, Touch and Go/Bolter Technique, and LSO Response. With some subtle differences, the squadrons appear to grade similarly during both qualification periods. (LSO's in VT-19 grade somewhat higher during July in the areas of Waveoff Technique, T&G/Bolter Technique, and LSO Response, and some what lower in the areas of Power control than they graded in May.)

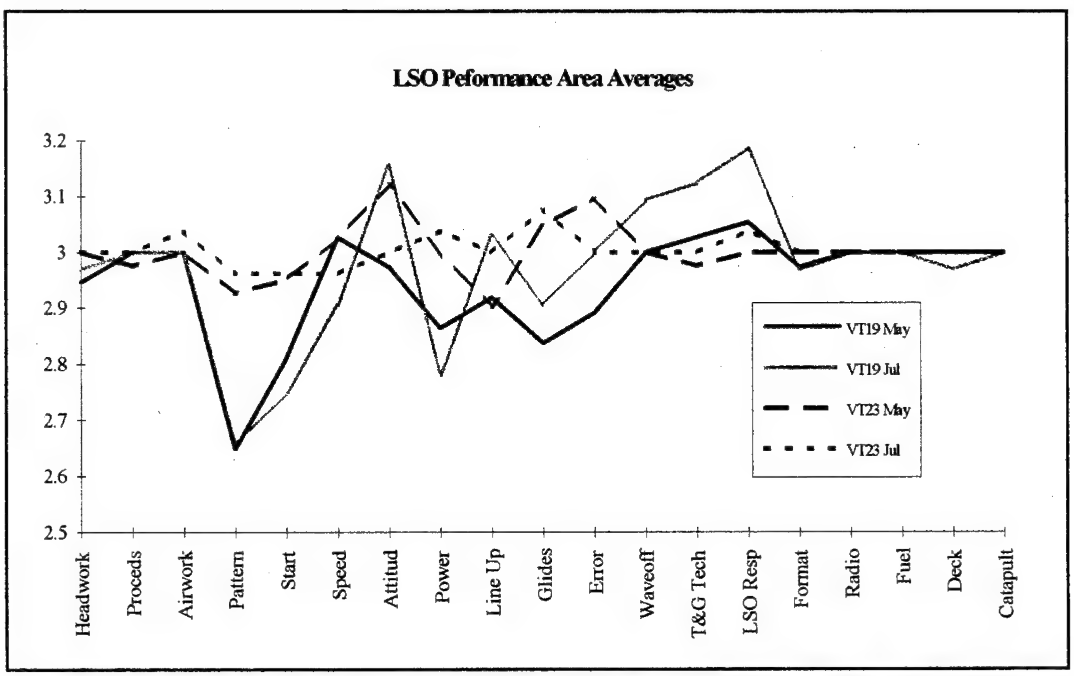

Figure 7: Squadron Performance Area Averages, Both qualification periods.

The data used to generate Figure 7 come from an ordinal scale of values "1", "2", "3", and "4". For all 19 performance areas, in both squadrons, the median value is "3", with numerous ties. Quantifying the differences identified in Figure 7 may well be a futile exercise, but two nonparametric tests are available for the processing of such data. The Median Test tests the hypothesis that all squadrons have the same median against the alternate hypothesis that the medians are different. As with the chi-square test, the Median Test requires an expected value of one in each cell to insure accuracy (Conover 1980, 172). Table 9 lists the results of the Median Test for each of the 19 performance areas. In most cases, data equal to three are counted as equal to or above the median. However in such cases where there are few or no data points below the median, data values equal to three are counted as below the median. Grades in Attitude Control, Error Detection/Correction, Waveoff Technique, Touch and Go/Bolter Technique, and Response to LSO are counted using the latter procedure.

Results of the Median Tests reject the equal median hypothesis for the performance areas of Pattern, Start Portion, Power Control, Glideslope Control, Touch and Go/Bolter Technique and Response to LSO. These six performance areas correspond to six of the eight areas identified in Figure 7. The two remaining areas, Error Detection/Correction and Waveoff Technique, did not fail the Median Test. It is interesting to note, though not surprising by any means, that the number of values above and below the combined median correspond to the averages illustrated in Figure 7. Thus, VT-19's Pattern average, much lower than VT-23, is reflected in the 25 values 'below the median' in Table 9, the highest count in this category. Likewise, VT-19 also had the highest average in LSO Response, and again, with a count of nine, has the highest count in the 'above the median' category. (Recall the rules for counting "3" as above or below the median.)

Performance Area	Median	# of Grades in VT-19		# of Grades in VT-23		df	Chi-square	p-value <
		< Median	>= Median	< Median	>= Median			
Headwork	3	3	70	0	63	1	2.65	0.104
Procedure	3	*	**	*	**	*	****	****
Airwork	3	*	**	*	**	*	****	****
Pattern	3	25	48	4	59	1	15.69	0
Start Postion	3	16	57	4	58	1	5.06	0.025
Speed Control	3	4	69	2	61	1	0.43	0.514
Attitude Control	3	66	7	58	5	1	0.11	0.735
Power Control	3	13	60	1	62	1	9.64	0.002
Line Up	3	8	65	5	58	1	0.36	0.55
Glideslope Control	3	15	58	1	62	1	11.71	0.001
Error Detection/Correctior	3	70	3	57	6	1	1.6	0.206
Waveoff Technique	3	70	3	63	0	1	2.65	0.104
T&G/Bolter Technique	3	68	5	63	0	1	4.48	0.035
Response to LSO	3	64	9	63	0	1	8.32	0.004
Formation/Pattern Entry	3	2	71	0	63	1	1.75	0.186
Radio Procedures	3	*	**	*	**	*	****	****
Fuel Management	3	*	**	*	**	*	****	****
Deck Procedures	3	*	**	*	**	*	****	****
Catapult Procedures	3	*	**	*	**	*	****	****

* Indicates all grades were 3 and Median Test was not warranted.

Table 9: Results of Median Test on Performance Areas.

The Median Test is a robust test, especially suited for data with expected outliers or error . Even though most of the performance grades in the squadrons are "3", whether grades of "1", "2", and "4" can be considered outliers is questionable. Consequently, a stronger nonparametric test was used to back up the results of the Median Test. The Kruskal-Wallis Test offers a nonparametric alternative to a one-way analysis of variance and tests the hypothesis that the squadron's grades for a specific performance area are identically distributed against the hypothesis that they are not identically distributed and their means are different (Conover 1980, 230). For this comparison, the performance area grade was used as the response variable and squadron was used as the factor. The Kruskal-Wallis Test ranks the data with "1" to the smallest data point, "2" to the next smallest, and so on to the largest data point. The ranks are then used to compute the test statistic. There is some disagreement surrounding how ties should be handled during the ranking process. Conover (1980, 232) advocates averaging the assigned ranks, so if the data has four values of "3", and "3" would have been the fourth rank, then the four values are initially ranked "4", "5", "6", "7" and then averaged so that all four have the rank 5.5. Lehmann (1975, 20) argues that such averaging makes the test invalid in data sets with large numbers of ties. He proposes an adjusted test statistic that divides the original test statistic by a factor that considers the number of tied data points. As pointed out in previous discussion, the performance area grades have numerous ties, most notably about the grade of 3. Because of the large number of ties, it is felt that Lehmann's adjusted test statistic is more relevant for the Kruskal-Wallis Tests that follow.

Table 10 presents the results of the Kruskal-Wallis Tests used to examine the individual performance areas. While the adjusted test statistic will be used for further analysis, p-values computed by both test statistics are listed in the table. The squadrons had different performance area means in six performance areas: Pattern, Start Position, Power Control, Glideslope Control, Touch and Go/Bolter Technique and Response to

Performance Area	VT19 Mean Grade	VT23 Mean Grade	df	Kruskal-Wallis (KW) Test Statistic	p-value	KW Test Statistic Adjusted	p-value
Headwork	2.96	3.00	1	0.17	0.68	2.63	0.105
Procedure	3.00	2.99	1	0.03	0.873	1.16	0.282
Airwork	3.00	3.02	1	0.03	0.873	1.16	0.282
Pattern	2.65	2.94	1	4.80	0.029	8.39	0.004
Start Postion	2.78	2.95	1	2.33	0.128	5.31	0.021
Speed Control	2.97	2.99	1	0.07	0.79	0.35	0.556
Attitude Control	3.06	3.06	1	0.05	0.831	0.15	0.694
Power Control	2.82	3.01	1	3.08	0.08	9.36	0.002
Line Up	2.98	2.95	1	0.10	0.753	0.26	0.61
Glideslope Control	2.87	3.06	1	2.53	0.112	5.09	0.024
Error Detection/Correctior	2.94	3.05	1	1.23	0.268	3.55	0.06
Waveoff Technique	3.05	3.00	1	0.17	0.68	2.63	0.105
T&G/Bolter Technique	3.08	2.99	1	0.70	0.404	5.52	0.019
Response to LSO	3.12	3.02	1	1.53	0.216	8.26	0.004
Formation/Pattern Entry	2.97	3.00	1	0.08	0.783	1.74	0.188
Radio Procedures	3.00	3.00	1	0.00	1.00	0.00	1.00
Fuel Management	3.00	3.00	1	0.00	1.00	0.00	1.00
Deck Procedures	2.98	3.00	1	0.02	0.891	0.86	0.353
Catapult Procedures	3.00	3.00	1	0.00	1.00	0.00	1.00

Table 10: Results of Kruskal-Wallis Test on Performance Area.

LSO. These are the same six areas identified by the Median Test. It is interesting to note that without the adjusted test statistic, the only significant performance area is Pattern, which is also the performance area showing the largest difference between squadrons in Figure 7.

It is clear from the above Kruskal-Wallis tests that students in VT-19 had lower grades in the four performance areas of Pattern, Start Position, Power Control, and Glideslope Control and higher performance grades in Touch and Go/Bolter Technique and Response to LSO. At this point in the analysis, it would seem appropriate to look at individual LSO difference, to determine if differences within a squadron contributed to the differences between the squadrons. Figures 8 and 9 illustrate the performance area averages of individual LSO's within VT-19 during the May and July qualification periods, respectively. In each of the graphs, if the all the LSO's gave an average of "3" in a performance area, that area has been removed from the graph.

In Figure 8, it can be seen that LSO A grades high when the other LSO's grade low and has a much lower grade in Glideslope control than any other LSO in the squadron. At first, glance VT-19 seems to have less variability in July (Figure 9) than it did during May. LSO A grades more similarly to the other LSO's, albeit somewhat higher in Attitude Control and Line Up. LSO C has a much higher grade in Response to LSO than the other LSO's. To examine the five LSO's in VT-19 more closely, Kruskal Wallis Tests, similar to the models used above, examined each performance area pictured in Figures 8 and 9. The Kruskal-Wallis Tests were conducted over both qualification periods, using the LSO's grades from both periods. Results of these tests are listed in Table 11. Italicized rows indicate a performance area that tested positively for significant difference between the LSO's, p-value < 0.05. Table 11 illustrates the variability between the LSO's in VT-19. Seven of the twelve performance areas examined have significant differences between LSO's. Of the six performance areas noted in Table 10, only Pattern was graded consistently by the LSO's.

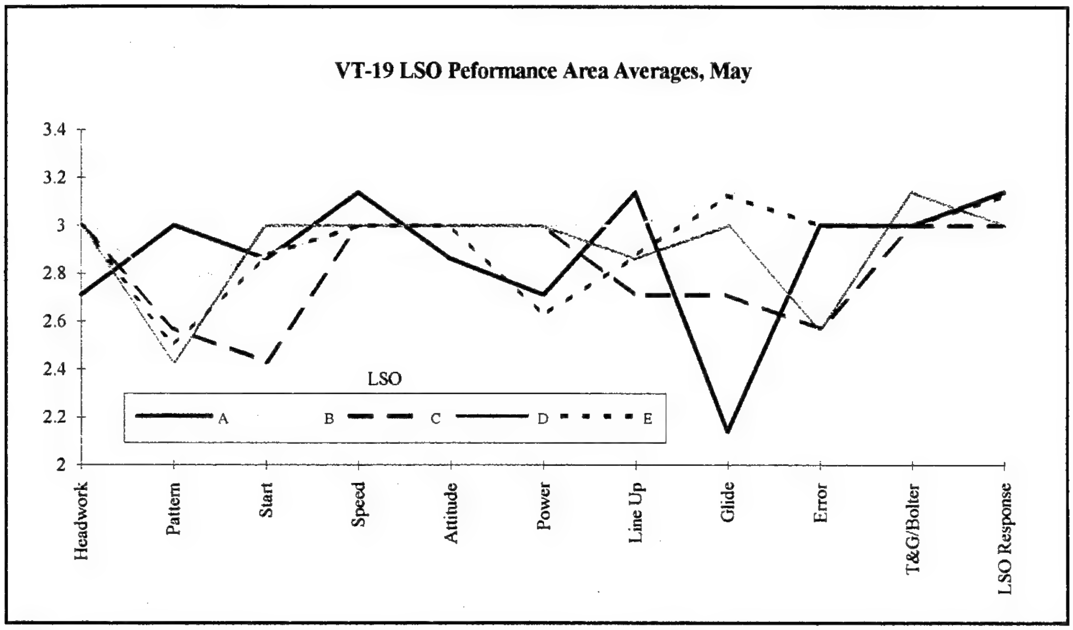

Figure 8: VT-19 Performance Area Averages, May.

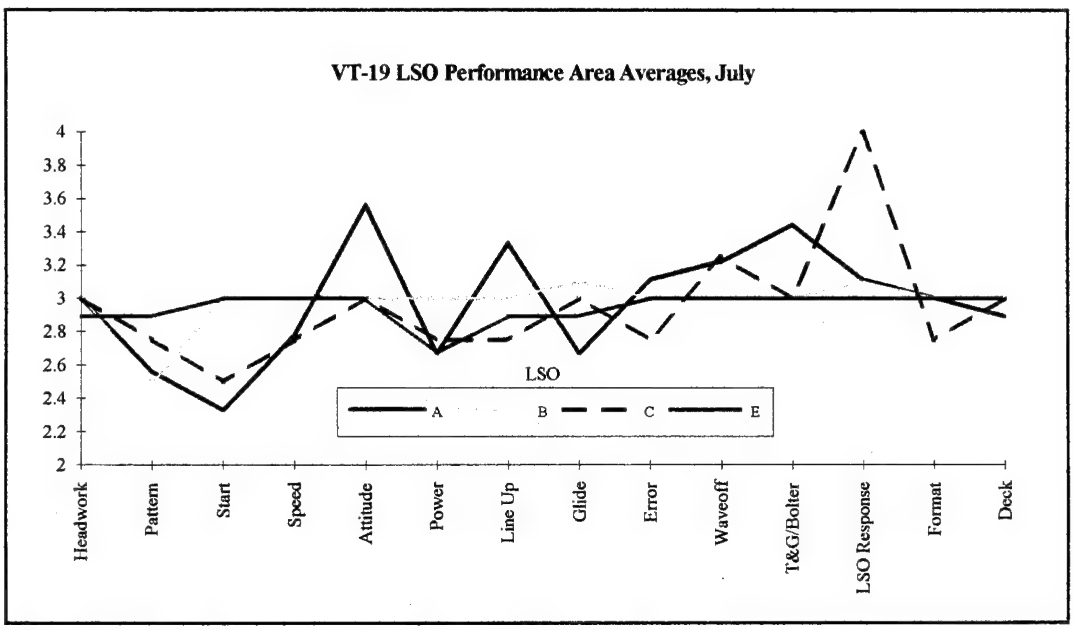

Figure 9: VT-19 Performance Area Averages, July.

Table 11: Results of Kruskal-Wallis Test on grades in selected performance areas by LSO's in VT-19, both qualification periods.

Performance Area	LSO A	LSO B	LSO C	LSO D	LSO E	df	Test Statistic Adjusted	p-value <
Headwork	2.87	3.00	3.00	3.00	3.00	4	4.23	0.377
Pattern	2.75	2.61	2.64	2.43	2.71	4	0.9	0.925
Start Postion	*2.56*	*2.94*	*2.45*	*3.00*	*2.94*	*4*	*16.88*	*0.002*
Speed Control	2.94	3.00	2.91	3.00	3.00	4	1.12	0.891
Attitude Control	3.25	3.00	3.00	3.00	3.06	4	5.85	0.211
Power Control	*2.69*	*3.00*	*2.91*	*3.00*	*2.65*	*4*	*9.58*	*0.049*
Line Up	*3.25*	*3.00*	*2.73*	*2.86*	*2.88*	*4*	*10.32*	*0.036*
Glideslope Control	*2.44*	*3.11*	*2.82*	*3.00*	*3.00*	*4*	*15.35*	*0.004*
Error Detection/Correction	*3.06*	*3.11*	*2.64*	*2.57*	*3.00*	*4*	*19.82*	*0.001*
Waveoff Technique	3.13	3.00	3.09	3.00	3.00	4	4.99	0.289
T&G/Bolter Technique	*3.25*	*3.00*	*3.00*	*3.14*	*3.00*	*4*	*11.44*	*0.023*
Response to LSO	*3.12*	*3.06*	*3.36*	*3.00*	*3.06*	*4*	*8.57*	*0.074*

Figures 10 and 11 illustrate the average performance grades in VT-23 during May and July qualification periods, respectively. Compared to VT-19, VT-23 displays much less variability. In May (Figure 10), no LSO stands out as an individual, although LSO J has higher averages in the areas of speed control and attitude. At first glance, Figure 11 looks disjointed and appears to suggest great variability between VT-23's LSO's during July. However, closer examination reveals that except for Line Up and Glideslope Control, only one LSO grades differently from the other five LSO's.

The lack of variability revealed in Figures 10 and 11 is reflected in the results of the Kruskal-Wallis Tests used to examine differences between the LSO's in VT-23 listed in Table 12. Only Attitude Control and Response to LSO display significant differences between the LSO's.

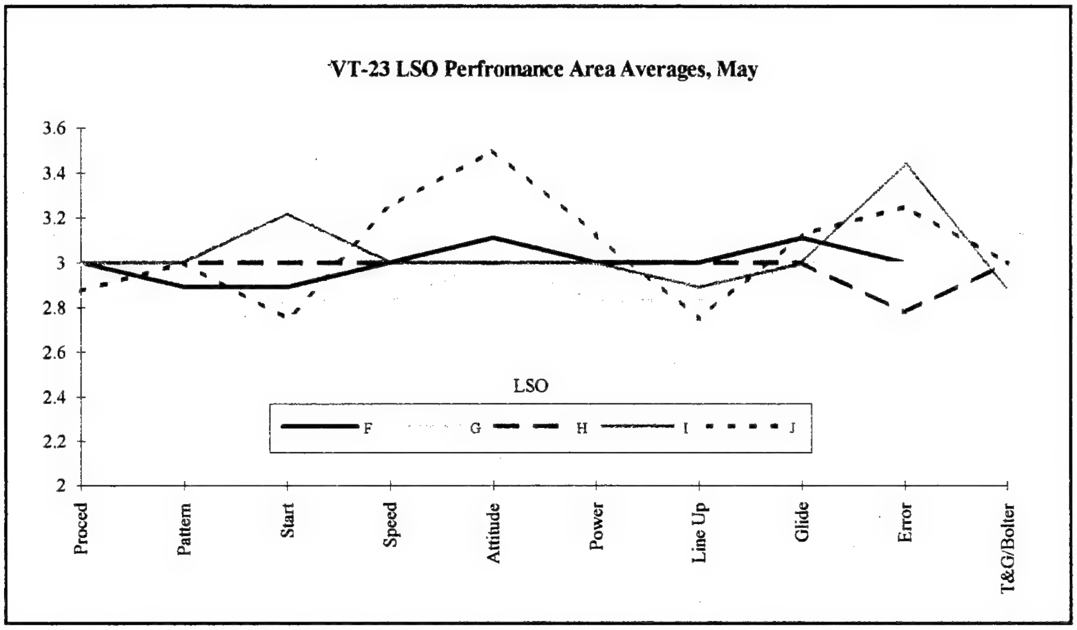

Figure 10: VT-23 Performance Area Averages, May.

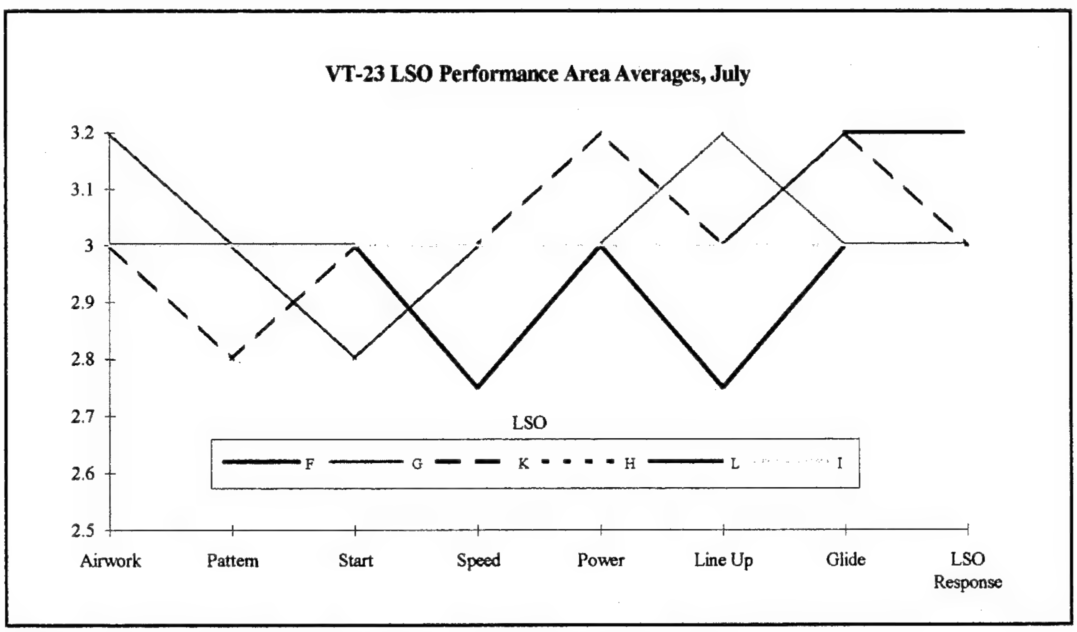

Figure 11: VT-23 Performance Area Averages, July.

Table 12: Results of Kruskal-Wallis Test on grades in selected performance areas by LSO's in VT-23, both qualification periods.

Performance Area	LSO							df	Test Statistic Adjusted	p-value<
	F	G	H	I	J	K	L			
Procedure	3.00	3.00	3.00	3.00	2.87	3.00	3.00	6	7.37	0.289
Airwork	3.00	3.00	3.00	3.00	3.00	3.00	3.20	6	12.4	0.055
Pattern	2.92	2.82	3.00	3.00	3.00	2.80	3.00	6	7.05	0.317
Start Postion	2.92	2.91	3.00	3.17	2.75	3.00	2.80	6	10.17	0.119
Speed Control	2.92	2.91	3.00	3.00	3.25	3.00	3.00	6	11.02	0.089
Attitude Control	*3.08*	*3.00*	*3.00*	*3.00*	*3.00*	*3.00*	*3.00*	*6*	*24.3*	*0.001*
Power Control	3.00	2.91	3.00	3.00	3.13	3.20	3.00	6	8.89	0.181
Line Up	2.92	3.00	3.00	2.92	2.75	3.00	3.00	6	4.85	0.563
Glideslope Control	3.08	3.00	3.00	3.00	3.13	3.20	3.20	6	4.17	0.654
Error Detection/Correction	3.00	3.00	2.85	3.33	3.25	3.00	3.00	6	12.4	0.055
T&G/Bolter Technique	3.00	3.00	3.00	2.92	3.00	3.00	3.00	6	4.85	0.563
Response to LSO	*3.00*	*3.00*	*3.00*	*3.00*	*3.00*	*3.00*	*3.20*	*6*	*11.44*	*0.023*

Thus comparison of LSO's within a squadron indicate considerable variability in VT-19 and somewhat less difference in VT-23. Of the six areas identified in Figure 7 and confirmed in Table 9 at the beginning of this chapter, only grades in Pattern can be considered unaffected by difference between the LSO's within a squadron. The differences in Pattern between the squadrons, appear to be just that, differences between the squadrons.

IV. DISCUSSION

Comparison of students in VT-23 to VT-19 revealed no significant differences in disqualification rates or LSO trend analysis scores. However, students in VT-23 had higher performance evaluations than students in VT-19. Moreover, the differences in performance evaluations appear to emphasize differences primarily in the area of Pattern. As Figure 7 and subsequent nonparametric tests indicate, VT-23 had higher grades in Pattern than students in VT-19. Isolating the cause of VT-19's higher Pattern grades, however, is a difficult task.

As has been discussed in previous chapters, LSO grades are somewhat subjective. Westra argues in his study that LSO grades are too subjective to form any concrete results. Westra points out that LSO's sometimes use grades as a motivational factor to encourage students to perform better in subsequent phases of their training, thus decreasing objectivity and validity (Westra et al. 1985, 41). However, Westra's study concentrated on the Field Carrier Landing Practice (FCLP) portion of the carrier qualification process and he studied only the LSO Trend Analysis Scores, not the CQ performance evaluations. (FCLP's are recorded on ATF's CQ-1x through CQ-10x.) When he considered the actual carrier qualification, the LSO grades for students who used the simulator were somewhat lower than the grades for students who did not use the simulator, but the difference was not statistically significant. In this study, students with exposure to the simulator had somewhat higher LSO trend analysis scores than students who did not have exposure, but the difference was statistically insignificant as well.

Examination of the CQ-11x Performance Evaluation Averages revealed significant differences, albeit across a small range, between students in VT-23 and VT-19. Further analysis identified the most significant difference between the squadrons appeared in the grades for Pattern. Nonparametric tests also identified significant differences in Start Position, Power Control, Glideslope Control, Touch and Go/Bolter Technique, and

Response to LSO. However, when these five performance areas are examined within individual squadrons, significant differences exist between the LSO's. Pattern is the only performance area without significant difference between LSO's within the squadrons.

The question still remains as to the cause of the difference in the Pattern Grades. Because each squadron used different LSO's, it is impossible to rule out grading differences between the squadrons. However, as the carrier qualification is the last requirement for the carrier qualification stage of their training, there is no longer the motivational requirement for grades suggested by Westra, therefore some of the subjectivity may be ignored. Indeed, previous research supports the claim that part of the difference in Pattern grades may be attributed to exposure to the visual simulator. Both Lintern and Westra found that use of a visual simulator improved their subject's spatial awareness. Lintern used a visual simulator to train beginning civil flight students before the landing phase of their instruction. He suggests that approximately 2 hours of landing training in a visual simulator can reduce the number of pre-solo landings in an aircraft (Lintern et al. 1990, 324). While Lintern admits to the possibility of instructor bias in determining the correct number of pre-solo landings, he attempted to counter such bias by not telling the instructors that the number of pre-solo landings would be the measure of effectiveness for the study. Westra found a significant advantage in approach lineup control for students who had trained on a visual simulator (Westra et al. 1985, 49). These findings were supported using equipment observations as opposed to human evaluation. For his study Westra used a special device that recorded the pilot's approach to the air field and recorded deviations from the correct line up approach.

A. THE IMPORTANCE OF PATTERN

At sea, Pattern is the element that drives a pilot's entire approach to the carrier. If the Pattern is correct, then the Line Up, Power Control, and Glideslope Control should follow closely behind. In the Flight Training Instruction Manual for the T-2C, it states: "**The landing pattern is the key to successful ball flying.** This cannot be emphasized enough. Your primary goal during the early stages of FAM [familiarization stage] is to

fly a consistent, precise, pattern resulting in consistent starts. When you are able to do so, then you can think about flying the ball (CNATRA P-650, 1993, 3-10 - 3-11)." Students begin practicing the proper landing problem in the second stage of their instruction. (Recall that the Carrier Qualification Stage occurs during the ninth and final stage of Intermediate flight instruction.) Figure 12 illustrates the standard approach pattern flown by students throughout their instruction. Although students are taught to make most of their turns using the cockpit instruments, they are also encouraged to use visual landmarks on the ground while learning the approach. These visual aids are not available to the student during a carrier approach, and while the student is constantly reminded of this fact, it must certainly be disorientating during the first few approaches to the ship. One advantage of the T-45 visual simulator may be an awareness of this spatial disorientation. In the simulator, the student is given an opportunity to observe the relatively small deck of a carrier against a massive, featureless ocean, and has the opportunity to witness a simulated instrument approach to the carrier. If two hours of visual simulator practice was enough to reduce pre-solo landing flights, then possibly two hours of simulator exposure is enough to enhance a student's awareness of the importance of instruments in flying the proper pattern. Such awareness might encourage students to place more emphasis on their pattern, thus resulting in better performance.

B. AREAS FOR FURTHER STUDY

At the completion of this thesis, approximately 121 students will have completed some portion of the T-45 training program, either by flying T-45A aircraft for their entire training or by transitioning to the T-45A for Advanced training after flying the T-2C for Intermediate training. As more T-45 aircraft are built, the T-2C and A-4 training squadrons in Meridian, Mississippi will eventually be phased out and all Naval jet flight training will be conducted in the T-45 aircraft.[4] Until this phase out is

[4]With the exception of those pilots designated to fly the E-2/C-2 Hawkeye Electric Reconnaissance Aircraft.

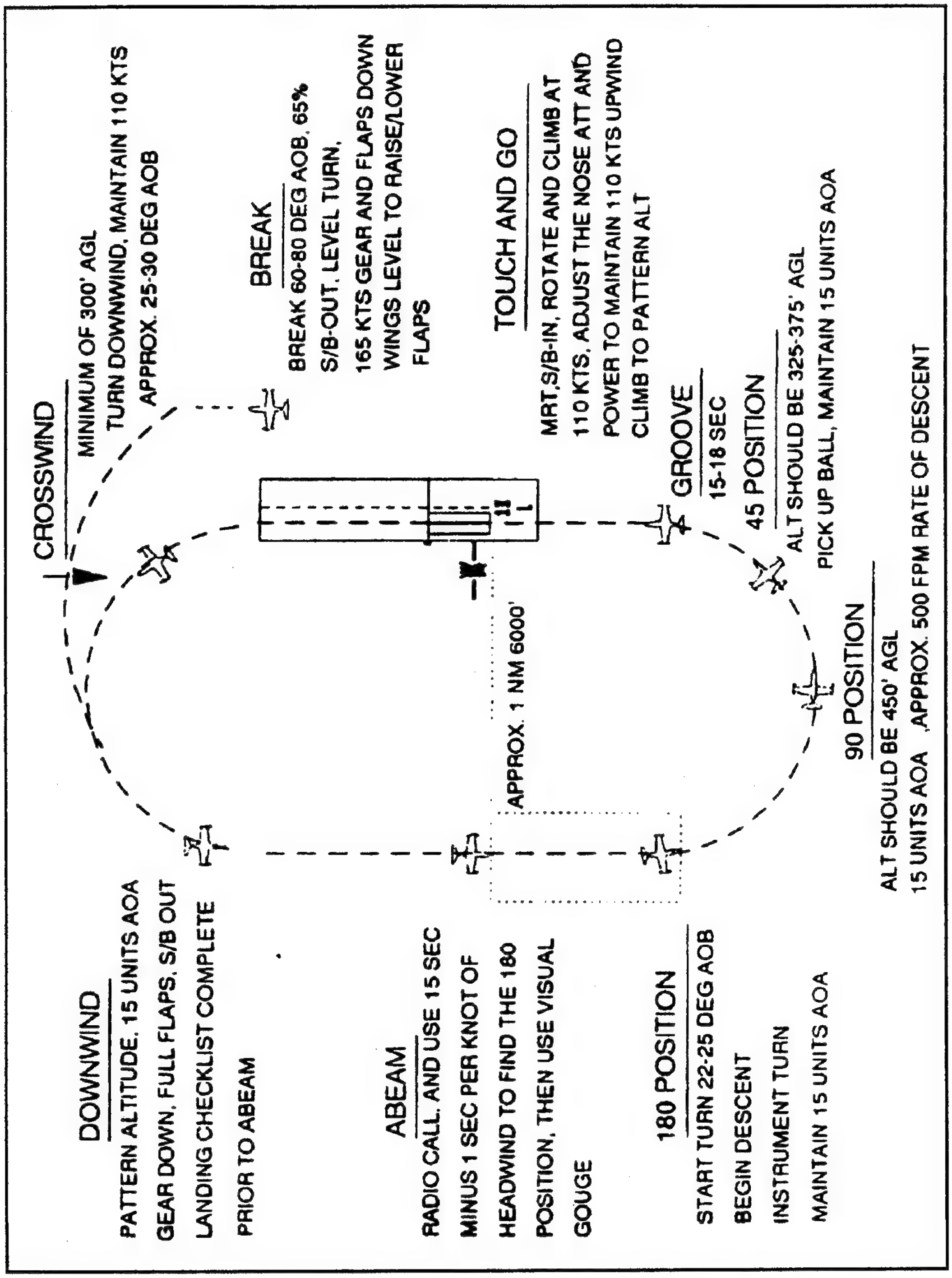

Figure 12: Standard Pattern Taught for Carrier Landings. (Flight Training Instruction: Intermediate Strike and Advanced E-2/C-2, September 1993, p. 3-13).

complete, however, the opportunity exists to compare the T-45 squadron in Kingsville to the A-4 squadron in Meridian. The T-45 training program has the ability to gather and record detailed data on students in the program. With prior planning, a similar recording system could be established for the A-4 program. Granted, the use of different aircraft introduces variance to the comparison, but such variance should not nullify all observations. In the long term, T-45 students should be, and undoubtedly are being, tracked as they progress beyond the training squadron. The integration of the T-45 students into the FRS and Fleet Squadrons should be compared to the integration of the A-4 students. Does the training program help the new aviators transition to their new platforms?

The emphasis of these comparisons must be on the training program. The T-45 training program is such a radically different approach to training, incorporating traditional lectures with high tech computer based training and visual simulators, it would seem impossible to isolate the effect of the visual simulator from the other training aides. However, as the simulator plays such an important role in the program, its effects will not be ignored.

V. CONCLUSION

This thesis compared two T-2C training squadrons to see if exposure to the T-45 visual simulator had any effects on student naval aviators during carrier qualifications. Student Naval Aviators in VT-23 received exposure to the T-45 simulator. SNA's in VT-19 did not train with the simulator. Both squadrons completed their final carrier qualifications concurrently, flying on the same aircraft carrier. Four measures of effectiveness were examined: Qualification Rates, LSO Trend Analysis Scores, Average CQ-11X Performance Evaluations, and grades in the Individual Performance Areas considered by CQ-11X. Comparison of the squadrons found no difference in qualification rates or LSO Trend Analysis Scores and significant differences in Average Performance Evaluations and in some Individual Performance Areas, most notably Pattern, Start Position, Power Control, Glideslope Control, Touch and Go/Bolter Technique, and Response to LSO. As this study compared grades based on human evaluation, some caution should be used in interpreting the results. However, the T-45 visual simulator does appear to have improved the ability of students to fly a proper pattern as they approach the aircraft carrier.

APPENDIX A. CARRIER QUALIFICATION ATF PERFORMANCE AREAS

	ATF				
Performance Area	**CQ-1**	**CQ-2x**	**CQ-3,4,5,6,7,8,9**	**CQ-10x**	**CQ-11x**
Headwork	X	X	X	X	X
Procedures	X	X	X	X	X
Basic Airwork	X	X	X	X	X
Pattern	X	X	X	X	X
Start Position	X	X	X	X	X
Speed Control	X	X	X	X	X
Attitude Control	X	X	X	X	X
Power Control	X	X	X	X	X
Line Up	X	X	X	X	X
Glideslope Control	X	X	X	X	X
Error Detection/Correction	X	X	X	X	X
Waveoff Technique	X	X	X	X	X
Course Rules	X	X			
Pattern Entry/Break	X	X			
Response to LSO		X	X	X	X
Progress			X	X	
T&G/Bolter Technique					X
Formation/Pattern Entry					X
Radio Procedures					X
Fuel Management					X
Deck Procedures					X
Catapult Procedures					X

APPENDIX B. LSO MARKS AND GRADES

Symbol	*Definition*	*Grade*
OK (underlined)	Perfect Pass	5.0
OK	Reasonable deviations with good corrections	4.0
(OK)	Fair, reasonable deviations	3.0
B	Bolter	2.5
-	Below average but safe pass	2.0
PWO	Power waveoff	2.0
OWO	Own waveoff	2.0
WO	Waveoff	1.0
C	Cut. Unsafe, gross deviations inside waveoff window	0.0

APPENDIX C. SUMMARY OF WEATHER OBSERVATIONS

USS AMERICA (CV 66), May Qualification Period

Date	Time Z	Location	Wind Direction	Wind Speed (kts)	Visibility (KM)	Temperature (celsius)
14-May	0001	N17.1 W065.3	080	22	10	28.3
	0600	N17.2 W065.8	100	18	10	26.1
	1200	N17.5 W066.3	110	17	10	26.6
	1800	N17.1 W065.6	110	14	20	27.8
15-May	0001	N17.2 W065.4	100	15	10	27.8
	0600	N18.5 W065.1	110	18	10	26.1
	1200	N18.9 W065.4	110	14	20	26.7
	1800	N19.4 W065.6	120	9	20	26.7
16-May	0001	N21.2 W066.6	110	8	20	25.6
	0600	N23.2 W066.5	180	9	10	25.0
	1200	N25.1 W068.5	030	8	20	24.5
	1800	N27.0 W069.5	010	10	20	25.0
17-May	0001	N28.8 W070.9	020	6	20	21.9
	0600	N30.7 W071.5	230	9	10	22.2
	1200	N32.6 W072.4	250	12	20	21.7
	1800	N33.9 W073.5	200	13	20	22.2
18-May	0600	N36.6 W075.2	080	10	10	17.2
	1200	N36.8 W075.2	130	2	Fog	16.1

Date	Time Z	Total Clouds (oktas)	Lower Clouds (oktas)	Cloud Height (ft)	Wave Height (m)	Ship Direction	Ship Speed (kts)
14-May	0001	7	2	1000-1999	1	W	1-5
	0600	4	2	3500-4999	1	W	16-20
	1200	2	2	2000-3499	1	NE	6-10
	1800	4	2	2000-3499	1	SE	6-10
15-May	0001	6	2	2000-3499	1	S	1-5
	0600	2	2	>8000	1	N	16-20
	1200	6	1	1000-1999	1	0	0
	1800	6	1	>8000	1/2	NW	11-15
16-May	0001	8	8	>8000	1/2	NW	21-25
	0600	3	3	>8000	1/2	NW	21-25
	1200	6	1	2000-3499	1/2	NW	16-20
	1800	6	1	2000-3499	1/2	NW	21-25
17-May	0001	4	2	2000-3499	1/2	NW	21-25
	0600	1	1	2000-3499	1/2	NW	16-20
	1200	1	1	2000-3499	1/2	NW	16-20
	1800	2	0	>8000	1/2	NW	16-20
18-May	0600	1	1	2000-3499	1	NW	16-20
	1200	8	4	300-599	1/2	E	6-10

USS JOHN F. KENNEDY (CV 67), July Qualification Period

Date	Time Z	Location	Wind Direction	Wind Speed (kts)	Visibility (KM)	Temperature (celsius)
23-Jul	0001	N30.9 W080.4	220	20	20	28.6
	0600	N31.0 W079.8	240	12	10	27.2
	1200	N30.9 W079.4	270	13	10	27.8
	1800	N31.2 W080.4	240	5	20	28.9
24-Jul	0001	N30.7 W080.8	220	15	20	26.7
	0600	N30.2 W080.1	210	12	10	26.1
	1200	N30.1 W079.9	260	8	20	27.8
	1800	N30.6 W079.8	240	5	20	30.6
25-Jul	0001	N30.2 W080.0	170	16	20	28.9
	0600	N29.9 W080.0	210	8	10	26.7
	1200	N30.0 W079.8	250	12	20	27.8
	1800	N30.5 W080.0	230	10	20	29.4
26-Jul	0001	N30.3 W080.5	170	10	20	26.7
	0600	N30.6 W080.0	250	10	10	26.7
	1200	N30.6 W079.7	280	20	20	27.2
	1800	N30.9 W080.1	250	6	10	26.7
27-Jul	0001	N30.4 W080.1	230	6	10	27.8
	0600	N30.7 W079.7	340	8	10	25.6
	1200	N30.8 W079.8	330	13	20	27.8
	1800	N31.0 W080.0	350	9	20	28.9

Date	Time Z	Total Clouds (oktas)	Lower Clouds (oktas)	Cloud Height (ft)	Wave Height (m)	Ship Direction	Ship Speed (kts)
23-Jul	0001	4	2	2000-3499	1/2	SE	16-20
	0600	3	0	>8000	1/2	NE	11-15
	1200	4	2	2000-3499	1/2	W	11-15
	1800	4	0	>8000	1/2	NW	16-20
24-Jul	0001	6	5	>8000	1/2	S	11-15
	0600	4	2	2000-3499	1	SE	11-15
	1200	6	2	2000-3499	1/2	W	11-15
	1800	6	3	2000-3499	1/2	E	11-15
25-Jul	0001	3	1	2000-3499	1/2	SE	16-20
	0600	2	2	2000-3499	1/2	S	6-10
	1200	5	1	2000-3499	1/2	W	6-10
	1800	6	2	2000-3499	1/2	N	11-15
26-Jul	0001	4	2	2000-3499	1/2	SW	11-15
	0600	1	0	>8000	1/2	NE	11-15
	1200	6	5	1000-1999	1/2	S	6-10
	1800	8	6	2000-3499	1/2	S	6-10
27-Jul	0001	4	1	>8000	1/2	NW	6-10
	0600	6	3	2000-3499	1/2	SE	1-5
	1200	5	1	2000-3499	1/2	N	11-15
	1800	3	2	2000-3499	1/2	SE	16-20

APPENDIX D. CONTINGENCY TABLES FOR COMPARISON OF SQUADRON DISQUALIFICATION RATES

Table D1: Contingency Table for May Qualification Period, Both Squadrons.

Squadron	Student Qualification	Student Disqualification	Total
VT-19	40	4	44
	40.46	3.54	44
VT-23	40	3	43
	39.54	3.46	43
Total	80	7	87
	80	7	87

Chi-Square 0.131 with D.F. 1

Cell Contents: Count
Expected Frequency

Table D2: Contingency Table for July Qualification Period, Both Squadrons.

Squadron	Student Qualification	Student Disqualification	Total
VT-19	36	2	38
	35.29	2.71	38
VT-23	29	3	32
	29.71	2.29	32
Total	65	5	70
	65	5	70

Chi-Square 0.443 with D.F. 1

Cell Contents: Count
Expected Frequency

Table D3: Contingency Table for VT-19, Both Qualification Periods.

Month	Student Qualification	Disqualification	Total
May	40	4	44
	40.78	3.22	44
July	36	2	38
	35.22	2.78	38
Total	76	6	82
	76	6	82

Chi-Square 0.441 with D.F. 1

Cell Contents: Count
Expected Frequency

Table D4: Contingency Table for VT-23, Both Qualification Periods.

Month	Student Qualification	Disqualification	Total
May	40	3	43
	39.56	3.44	43
July	29	3	32
	29.44	2.56	32
Total	69	6	75
	69	6	75

Chi-Square 0.143 with D.F. 1

Cell Contents: Count
Expected Frequency

Table D5: Contingency Table for Both Squadrons, Both Qualification Periods.

Squadron	May Students Qualification	Disqualification	July Students Qualification	Disqualification	Total
VT-19	40	4	36	2	82
	41.78	3.66	33.95	2.61	82
VT-23	40	3	29	3	75
	38.22	3.34	31.05	2.39	75
Total	80	7	65	5	75
	80	7	65	5	75

Chi-Square 0.786 with D.F. 3

Cell Contents: Count
Expected Frequency

APPENDIX E. ANALYSIS OF VARIANCE MODEL USED FOR LSO TREND ANALYSIS AND CQ-11X PERFORMANCE EVALUATION COMPARISONS

The same model is assumed for both analyses. Recall that data has been observed in each of two months (May, July) for each of two squadrons (VT-19, VT-23). Each squadron has its own set of LSO's, assumed to be selected at random from a pool of such people; some LSO's participated in both qualification periods, some did not. The number of students graded by a given LSO also varies. Letting y_{ijkl} represent the l^{th} grade given by LSO k in squadron i during month j. The model states that:

$$y_{ijkl} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_{(ij)k} + \varepsilon_{ijkl}$$

where α_i = effect due to month i,

β_j = effect due to squadron j,

$(\alpha\beta)_{ij}$ = effect of the interaction of month i with squadron j,

$\gamma_{(ij)\mathrm{k}}$ = effect of LSO k (nested within month/squadron, combinations), and

ε_{ijkl} = effect due to error from grade l by LSO k in squadron i, during month j

for i = 1,2,

j = 1,2,

k = $1 \ldots n_{ij}$, where n_{ij} is the number of LSO's in squadron i during month j, and

l = $1 \ldots n_{ijk}$, where n_{ij} is the number of grades given by LSO k in squadron i during month j.

It is assumed that the α_i, β_j, $(\alpha\beta)_{ij}$ values are unknown constants, or fixed effects, while $\gamma_{k(ij)}$ are independent, normal $(0, \sigma^2_\gamma)$, random effects and ε_{ijkl} are independent, normal $(0, \sigma^2)$ and mutually independent of the $\gamma_{(ij)k}$ random effects.

As the number of LSO's varies by squadron and month and the number of students graded by a given LSO also varies, the data available is unbalanced. The unbalanced characteristic of the data causes the estimates of the fixed effects to be nonorthogonal or correlated. As a result, the effects of month, squadron, and their interaction, as measured by the reduction in the residual sum of squares given by their inclusion in the model, depends on the other terms already in the model. In other words, when month enters into the model, its effect will depend on the other terms entered into the model before month. A different fixed effect may result if month had entered the model first. To compensate for the correlation in the data, the significance of these fixed effects is judged by their "marginal" reduction in the residual sum of squares, the reduction caused if all other terms are also in the model. For example, the adjusted sum of squares for month is the difference between the residual sum of squares when the the model considers all variable *except* month and the residual sum of squares when the model considers all variables *including* month.

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